

CORNING GLASS WORKS
ELECTRO-OPTICS LABORATORY
RALEIGH, NORTH CAROLINA

IMPROVED SCREEN FOR REAR PROJECTION VIEWERS

Technical Report No. - 31

Date - August 16, 1968

Period Covered - June 17, 1968

to

August 16, 1968

STAT

TECHNICAL REPORT NO. 31

I. GENERAL

Work on random diffusing screens has continued since December, 1967. This work solved some problems, uncovered new problems and generally confirmed the view that only minor improvements to random diffusing screens are possible. A lenticular scheme was devised that appeared to solve some of the fabrication problems. Due to the greater improvements conceptually achievable with lenticular screens it has been agreed with the agency that the main effort in this contract would be devoted towards achieving a practical lenticular screen.

This report summarizes the work since December, 1967 and outlines one lenticular screen concept.

II. Discrete-particle Screens

Discrete-particle screens have, up to this point, been plagued with difficulties both in their fabrication, appearance, and their optical properties. These screens consisted of aluminum oxide particles between 0.5 and 10 μ in diameter (average 3 μ) suspended in a transparent binder and applied as a 25 μ thick layer on glass substrates. Fabrication problems have centered around having the necessary viscosity of the screen material just prior to fabrication, and not being able to have the desired optical properties at the same time. Several of the ammonium based thickening agents used to adjust viscosity generated gas in the mixture giving poor quality screens. In addition, the binding materials were sensitive to physical damage as well as to organic cleaning agents and to water. Those screens which were fabricated tended to show streaks along one direction.

While resolution was very good, the combination of optical properties affecting efficiency and contrast in ambient light, i.e. T_{90} , T_{45} , R_d , and axial gain of these type of screens was usually poor. For example, on axis a

screen might appear to be high gain but over a considerable range of angles it appeared very uniform. This gave a noticeable hot spot in the direction of the projection lens. On occasion some screens were specular, on axis, and uniform at all other angles. In addition, these screens had excessive sensitivity to ambient light.

III. Ground Glass Screens

Superior screens consisting of ground glass in a compatible binder have been fabricated. The optical properties are easily controllable over a wide range of axial gains and no excessive sensitivity to ambient light has been found. These new screens are extremely resistant to physical damage and can be easily cleaned in mild detergent solutions. Practical tests clearly indicate that part of the scattering comes from the difference in refractive index between the glass particles and the binder and some from the microscopic surface structure of the scattering layer. Some problems may therefore exist if a separate absorbing layer is added over the scattering layer.

1. Investigation of Darkened Substrates

All known high resolution rear-projection screens are fabricated by forming a diffusing layer on a clear substrate. These screens are made less sensitive to ambient light by adding an absorbing material to the diffusing layer. This is undesirable not only because the efficiency of the projector is reduced, but also because a significant fraction of the internally trapped projection and ambient illumination passes through very little of the absorbing material. This trapped light is responsible for degrading the image contrast.

A slightly more effective way of reducing these internal reflections and the diffuse reflectance, would be to place an absorbing layer in optical contact, and

over the viewing side of the diffusing layer. This ensures that all the diffusely reflected ambient light passes completely through the absorbing layer twice. The absorbing material is now more effective for a given loss of projection irradiance; therefore, less absorption is needed and the efficiency of the projection system slightly improved.

A limited number of screens consisting of separate scattering and absorbing layers have been fabricated using a carbon dispersion as the absorbing material. Measurements of the parameters of these screens are planned. Tests using a diffusing screen and several interchangeable absorbing layers indicate that the diffuse reflectance of the screen falls as the square of the transmittance of the absorbing layer.

IV. Lenticular Screens

Lenticular, or lens-like, screens operate by refraction of light rather than by light scattering. A typical screen might consist of a plane matrix of very small lenses. Each small lens acts as an image transfer element, taking a small element of an image, which is projected on the screen, and transmitting and spreading the light from it over the viewing field. The size of the individual lenticules must be kept small if good resolution properties are to be obtained.

An ideal rear-projection screen, for most applications, would have 100% transmission efficiency, constant brightness within a specified range of viewing angles, and zero diffuse reflectance. The impossibility of obtaining a scattering screen which simultaneously satisfied these requirements has been established. Lenticular screens, however, are not subject to the same trade-offs and limitations as scattering screens. Properly designed lenticular screens can conceivably approach these ideal requirements, provided that

care is taken to avoid total internal reflection of projector light and that the lenticules are close-packed, i.e. no void areas. If these conditions are met then the efficiency of lenticular screens is limited only by surface reflection losses. Ambient light sensitivity can be kept small by designing the screen to transmit or absorb the ambient light. The large range of angles at which ambient light strikes all points of the screen leads to the use of an absorbing mask on the viewing side. All the projector light is focused through small openings in the mask.

By the use of an aspheric shape for the individual lenticules, screens exhibiting constant brightness over a specified range of viewing angles are possible, without a sacrifice in efficiency. Spherical lenticules will give an approximation to constant brightness at smaller viewing angles. The only mechanism for color distortion in lenticular screens is dispersion, which is a small effect compared to the the wavelength dependence inherent in scattering screens. It is because of these inherent advantages that the main emphasis over this contractual period will be on lenticular type screens.

The major problems still to be solved, in the development of practical lenticular screens are those relating to fabrication, i.e. forming and assembly. The periphery of the individual lenticules must have a shape which allows close-packing with no void areas; e.g. triangular, rectangular, hexagonal, etc. The brightness uniformity of lenticular screens is dependent on lenticule curvature, so it is desirable that this curvature be controllable. Workable masking techniques are needed in order to obtain superior ambient light sensitivity characteristics. All of these problems are made more complex by the requirement of small close-packed lenticules, preferably less than 20 microns in diameter, to meet resolution requirements.

Based on the preceding discussion, the following program for development of lenticular screens will be:

1. Seek configurations which will allow the realization of the conceptual advantages. These configurations will be analyzed to determine the screen properties expected.
2. Investigate promising materials and techniques applicable to the fabrication and masking of lenticular screens.
3. Fabricate sample screens for evaluation of their optical properties and of the various fabrication approaches used. One approach to be tried is to form a long block of glass with a cross section as shown in Fig. 1. The special lenticular shaped components are ground from glass plates. These are then assembled and fused together along with the absorbing glass, which constitutes the ambient light rejecting mask, to form a solid block of glass. This block is redrawn into ribbon, which reduces the size of the lenticles, but preserves their shape. Strips of this ribbon are laid down side-by-side and fused to a thick plate of glass for structural purposes. This is again redrawn into ribbon reducing the size of the individual lenticular elements still further. Strips of this ribbon are finally fused together on another plate to form part of the final screen.

These lenticles will necessarily be cylindrical thereby spreading light in only one plane. Two plates of these elements can be positioned at right angles to each other, giving full coverage to a viewing area. Different viewing angles in the horizontal and vertical planes can be achieved by making the shape of the lenticular plates different for the two plates.

V. Reduction of Surface Reflections

Surface reflections will determine a lower limit to the diffuse or specular reflectance obtainable with all rear-projection screens. A rough surface towards the viewer will give diffuse reflectance and a smooth surface will give specular reflectance. Surface reflections will also cause loss of screen efficiency although this loss will be much less significant for the system than will the ambient light reflection.

Typically, an air to transparent material interface gives about 5% reflection up to about 45° for unpolarized light. As the angle approaches 90° , the reflectance approaches 100%. One common approach to reduce surface reflections is by special thin film antireflection coatings. One or more layers of thin material of carefully chosen refractive index and thickness are commonly used. Reflectances of below 1% over the visual waveband from 0 to 45° angle of incidence can be obtained.

Investigation of low temperature coatings, suitable for application to plastic substrates, is planned. Several facilities capable of coating large area substrates have been identified. The uniformity, designs available, and economies of coating large area substrates has yet to be determined.

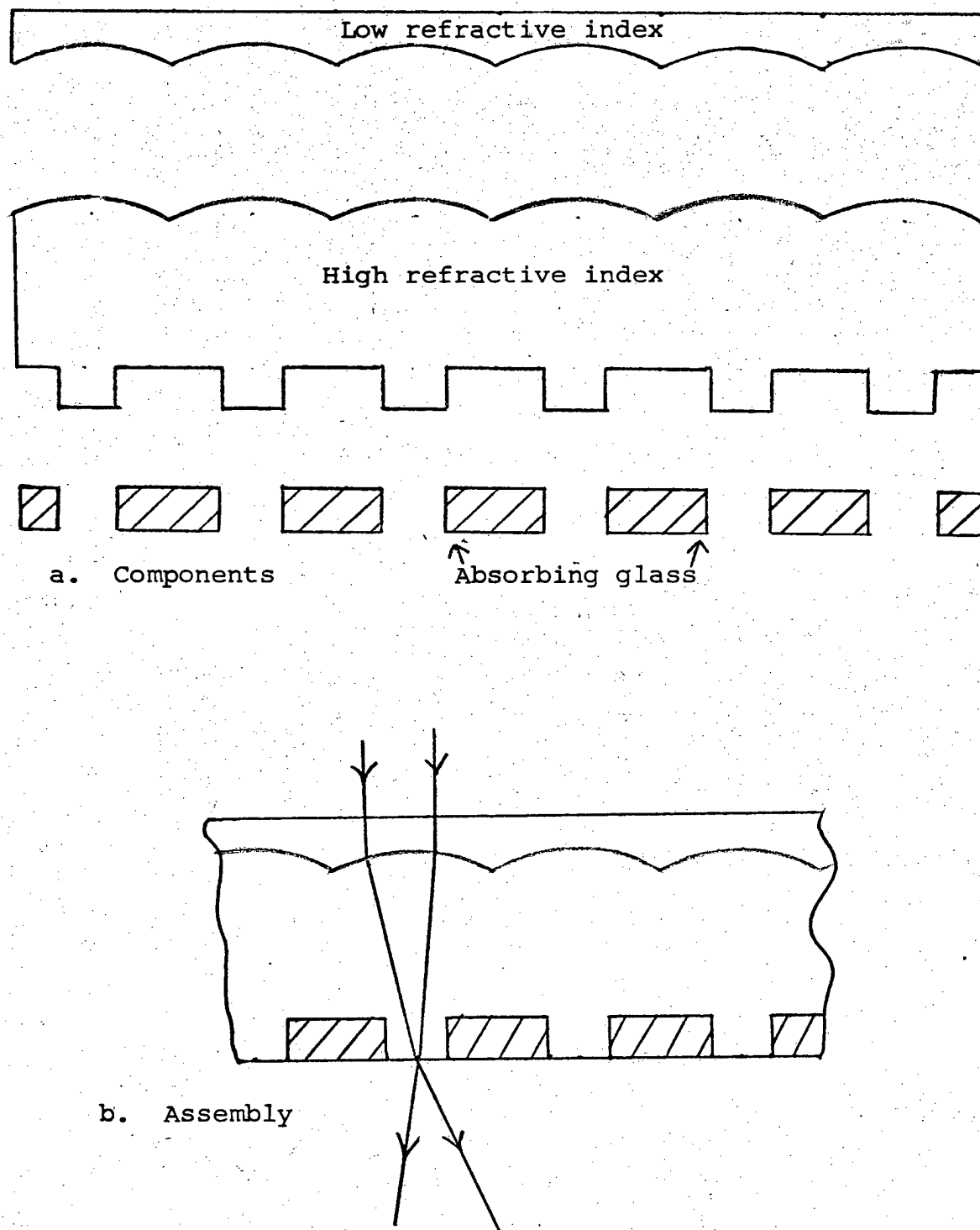


Fig. 1. Cylindrical lenticular lens scheme.